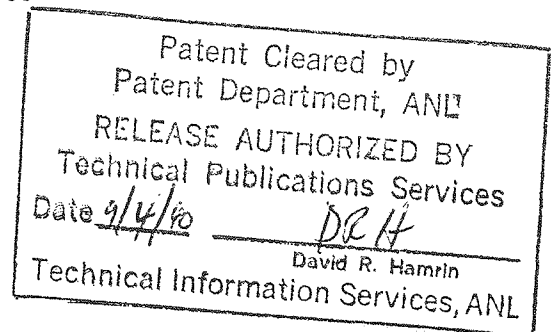71231

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RESULTS OF DESIGN CALCULATIONS
FOR THE MODULATOR OF THE
CROSSED FIELD UNDULATOR DEVICE

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Abstract:

The modulator in the crossed field undulator device is used to shift the phase of the radiation of undulator B with respect to undulator A. The phase shift range is zero to 2π for every wavelength between 100Å and 1500Å. The switching frequency between two distinct polarization states can be as high as 10Hz. Results of calculations for a specific modulator design are presented in this note.

Introduction

Kim[1] proposed a system to produce synchrotron radiation with variable polarization that consists of two consecutive undulators and a phase shifter between the two undulators (U), called UA and UB. The orientation of the magnetic field of UB is rotated with respect to UA by 90 deg. around the electron beam. The synchrotron radiation produced by UA and UB is linear (on axis), with the two wave vectors of the radiation perpendicular to each other. A variety of different polarization states can be produced by changing the phase of the radiation of UB with respect to the radiation from UA.

The phase shifter is a short electromagnetic wiggler, called a modulator. The magnetic field in the modulator forces the electrons to oscillate around the center line of the device. Therefore, the path length of the electron beam through the modulator is larger than the path length of the radiation from UA, that passes in a straight line through the modulator. This difference of path length is proportional to the phase shift, and can be adjusted by changing the current in the modulator coils. The rate of change is limited by the power supply, and the eddy currents in the steel core, in the conductor of the modulator coils, and, possibly, in the vacuum chamber. A 10Hz switching frequency between full current through the coils and no current through the coils seems to be feasible.

The Modulator

The main requirements for the modulator are:

- The modulator must be able to change the phase of the longest wavelength of interest, i.e. 1500Å, by up to 2π.
- The switching frequency between two specific polarization states can be as high as 10Hz.
- The steering and displacement of the electron beam due to the modulator is negligible.

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[1] K.-J. Kim, NIM 219, 425 , 1984.

The modulator is a five pole wiggler with a fixed 5 cm gap. In the current design, the modulator is oriented so that the magnetic field in the device is parallel to the field in one of the undulators. Fig. 1 shows a longitudinal section through the modulator. The two end poles have no coil and are only half as thick as the inner poles. The end poles serve as field clamps that reduce the stray field of the modulator and the sextupole coefficient of the field integral. The center pole and the two side poles can be energized with coils. As long as the permeability is large enough within the steel the current in the center coil should be twice the current in a side coil to avoid steering the electron beam[2]. Therefore, if the center coil has twice as many turns as the side coil, the magnet can be driven by one power supply.

The design of the modulator is based on theoretical work done by K. Halbach[3]. The highest magnetic flux density occurs at the base of the center pole where the average flux density should be well below the saturation field of vanadium permendur. Assuming infinite permeability, the average flux density at the base of the pole can be calculated as a function of pole height and phase shift. This design was checked with the 2D-Magnet Code POISSON using a measured B-H curve[4] for vanandium permendur. The computer calculations showed that at up to 80% of the design current, the steering of the electron beam is small ($<30\mu$rad) compared with the minimum width of the first harmonic radiation cone of UA ($\approx 280\mu$rad). The phase shift at 80% of the design current is 2π for a wavelength of 1300Å. Due to the beginning of saturation, the steering of the electron beam increases to 140μm at 100% of the design current (600A).

To avoid the saturation problem, a vacuum chamber with a slightly reduced vertical clearance and having the modulator vertically oriented should be considered. This could lead to a significant improvement of the modulator performance at large phase shifts and large wavelengths.

The cooling requirements for the coils were specified by assuming that 100% of the design current is flowing in the modulator coils and that the increase in cooling water temperature in a main coil is ΔT=10K. The necessary water flow is $\approx$30 cm^3/s (0.46 gal/min); the pressure drop over one main coil is about 5.1 bar (72 psi). The total power dissipated in the modulator is about 3.6kW, the ohmic voltage drop is 6V. Additional heat is dissipated when the modulator is driven with alternating current with a frequency of 10Hz and an amplitude of 300Å.

[2] K.Halbach, "Desirable excitation patterns for tapered wigglers", NIM A 250,1986, 95-99

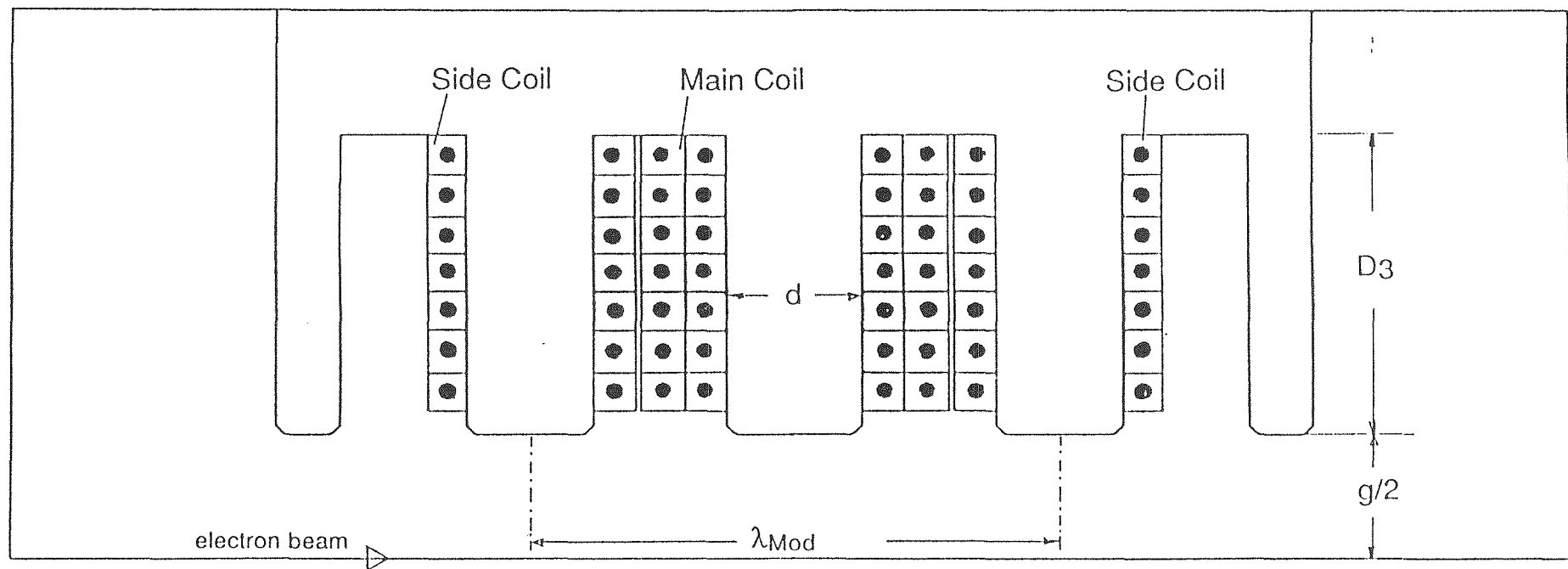[3] K.Halbach, presentation at the 3rd CUA Workshop at LBL., Ca., Feb. 23,1990.

[4] LBL

Fig1: Longitudinal section through the modulator (schematic).

However, the power dissipation due to eddy currents in the conductor (<16W) and in the steel laminations (<1W) are small. Also the power dissipation in the steel due to hysteresis losses is quite small (<0.1W). The total voltage in the alternating current case is less than 12V.

The data of the modulator are summarized below:

Total length		20.00 cm
Period length	λ_u	10.00 cm
Gap	g	5.00 cm
lateral width	b	8.00 cm
pole thickness	d	2.50 cm
pole height	D_3	6.10 cm
Coil wire outer dia	d_a	6.48 mm
Coil wire inner dia	d_i	3.15 mm
Maximum Current	I	600.0 A
Total ohmic loss	P	3.60 kW
Water flow (main coil)		30 cm^3/s
Pressure drop (main coil)	Δp	5.1 bar